



Blood Volume and Other Hematologic Values in Young Elephant Seals (*Mirounga angustirostris*)

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SUMMARY

The blood volumes of 7 young northern elephant seals (*Mirounga angustirostris*) were analyzed by dilution of ^{131}I -labeled human serum albumin. Microhematocrit values were also determined. Using these techniques, a mean blood volume of 216 ml./kg. and a mean packed cell volume of 64% were determined for these diving mammals.

It has long been known that diving animals usually have greater blood volumes than nondiving animals. Bert¹ reported that the blood volume was greater in ducks than in hens. Bohr² reported the blood volumes of the puffin (*Mormon fratercula*) and the guillemot (*Uria troile*) to be greater than those of non-diving birds. Ridgway and Johnston,¹¹ using radioiodinated (^{131}I) human serum albumin, reported the blood volume of the Dall porpoise (*Phocoenoides dalli*), a pelagic deep-diving animal, to be twice that of the less active, in-shore Atlantic bottle-nosed dolphin (*Tursiops truncatus*). Harrison and Tomlinson⁷ reported that the blood volume of the harbor seal (*Phoca vitulina*) is about 64% greater than that of man (11% of body weight in harbor seals, using the Evans blue method, compared with 7% in man). Wasserman and Mackenzie¹⁵ reported

values as high as 17.9% of body weight in *P. vitulina*, using ^{131}I -labeled human serum albumin. Scholander¹³ exsanguinated 2 young hooded seals (*Cystophora cristata*) weighing 25 and 28 kg. each and collected blood equivalent to 9 to 10% of body weight. He pointed out, however, that "... in the case of seals, due to their enormous system of veins," the technique probably accounted for no more than 75% of the total volume.

Harrison and Tomlinson^{7,8} surveyed the anatomic and physiologic features in aquatic and amphibious mammals that might be associated with prolonged submersion on deep diving. They concluded that the presence and relative development of the caval sphincter, hepatic sinus, retia (or venous plexuses, particularly in the thorax), and extradural intravertebral veins were significant features relative to diving capability of the species examined. The authors found such adaptations most prominent in the elephant seal (*Mirounga leonina*) and in the Ross seal (*Ommatophoca*

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TABLE 1—Blood Volumes of Elephant Seals

| Seal identification | Sex | Date of test | Weight (kg.) | Packed cell volume (%) | Blood volumes | |
|---------------------|-----|--------------|--------------|------------------------|---------------|------------|
| | | | | | In liters | In ml./kg. |
| M.a. 1 | F | 4/27/66 | 45 | 58.0 | 8.3 | 184 |
| | | 5/5/66 | 49 | 55.0 | 10.7 | 218 |
| M.a. 2 | F | 10/15/66 | 95 | 59.0 | 14.3 | 175 |
| | | 11/15/66 | 100 | 63.0 | 19.2 | 192 |
| M.a. 3 | F | 4/10/69 | 94 | 67.0 | 22.6 | 242 |
| | | 5/14/69 | 96 | — | 22.3 | 232 |
| | | 7/2/69 | 96 | 68.5 | 20.7 | 223 |
| | | 1/13/70 | 106 | 59.0 | 23.6* | 223* |
| M.a. 4 | F | 6/24/69 | 84 | 68.0 | 15.8 | 223 |
| M.a. 5 | F | 6/24/69 | 125 | 66.5 | 31.1 | 249 |
| M.a. 6 | F | 6/24/69 | 187 | 66.0 | 34.9 | 186 |
| M.a. 7 | F | 6/24/69 | 99 | 69.0 | 25.3 | 256 |

*Evans blue dye technique.

rossi). Blood volumes in the southern elephant seal (*M. leonina*) were determined by exsanguination to vary from 11% of body weight in the newborn to 16% in the adult and, in 1 adult female to be 207 ml./kg. as determined by Welcker's method.^{2,4} Elsner *et al.*⁵ reported the blood volume of a northern elephant seal by the direct exsanguination and oxygen capacity method to be 12% of body weight.

The elephant seal is known to spend as much as 40 minutes submerged¹⁴ and to dive as deep as 183 meters,¹² making it one of the most prolonged divers among seals and sea lions. The purpose of the present investigation was to determine the blood volume in the northern elephant seal (*M. angustirostris*) by a method that can be accurate to 2%.⁹

Materials and Methods

Seven northern elephant seals were used. On the basis of size and weight, the seals were estimated to be between 6 months and 3 years old. An injection of 10 μ Ci of radioiodinated (¹²⁵I) human serum albumin* in a 1-ml. volume was made into the right extradural vein (lying lateral to the spinal cord) of each seal. Ten minutes after the isotope was administered, a 10-ml. sample of blood was collected from the left extradural vein for counting and packed cell volume determinations. The average count of two 4-ml. portions was used in the blood volume calculations.

* Abbott Laboratories, North Chicago, Ill.

A standard dilution was prepared by bringing a 1-ml. amount of the injection solution to a 2,000-ml. volume with 1% calf serum in isotonic sodium chloride.⁶ The serum was added to prevent denaturation of the albumin. A 4-ml. sample of blood from each seal and the standard were counted in a 7.6- by 7.6-cm. sodium iodide well-crystal with a single channel pulse height analyzer.⁷

Blood samples were collected from 1 seal (M.a. 3) at 10, 20, 30, 90, and 240 minutes after injection and were counted. An Evans blue⁸ dye dilution blood volume determination was also performed on seal M.a. 3. Five milliliters of a 0.5% aqueous solution was injected. Injection and sampling techniques were the same as for the radioisotope method. Samples were collected 10 and 30 minutes after injection. Photometric analysis was made on a colorimeter.⁶

Results

Calculated blood volumes and microhematocrits for the 7 elephant seals are shown (Table 1). Eleven determinations with radioactive iodinated human blood serum albumin yielded a mean blood volume of 216.0 ml./kg. \pm 28.1 ml./kg. for these seals. The mean packed cell volume was 63.5%.

The data from the blood volume determinations with Evans blue (seal M.a.

⁶ Baird Atomic, Inc., Cambridge, Mass.⁷ Warner-Chilcott Laboratories, Morris Plains, N.J.⁸ Spectronic 20, Bausch and Lomb, Rochester, N.Y.

3) are also shown (Table 1). The samples collected 10 and 30 minutes after injection were identical in optical density.

The level of radioactivity in the blood of elephant seal M.a. 3 after it was injected with labeled human serum albumin is shown (Fig. 1). The measurement at the 30th minute postinjection was decreased only 2.7% from that at the 10th minute. This seal had been given human serum albumin on 3 previous occasions for blood volume determinations (Table 1). If an immune reaction existed, the rate of disappearance of the radioactive iodinated human blood serum would be greater than the removal rate when a seal is first exposed to this foreign protein.

Discussion

It is possible that the use of radioactive iodinated human serum albumin for blood volume determinations in species other than man can yield erroneous data due to its rapid removal by the reticuloendothelial system of the animal. Results of monitoring the blood of an elephant seal for 4 hours indicated that the disappearance rate of radioactive iodinated human blood serum albumin is less than 1%/10 minutes. This rate is certainly within acceptable limits for determinations of blood volume by radioisotope dilution. The similar activity of the 10-, 20-, and 30-minute samples demonstrates that a 10-minute mixing time is sufficient for thorough dilution. Results using Evans blue dye dilution that have a close correlation with the labeled albumin values also demonstrate that immunologic factors were not significant in the present studies. Together, these results demonstrate that labeled human albumin can be used as an accurate measure of blood volume in the elephant seal.

In a variety of mammals, there seems to be a correlation between blood volume and the natural behavior and environment of the animal.^{10,11} One may assume that blood volume is directly related to physiologic demand.

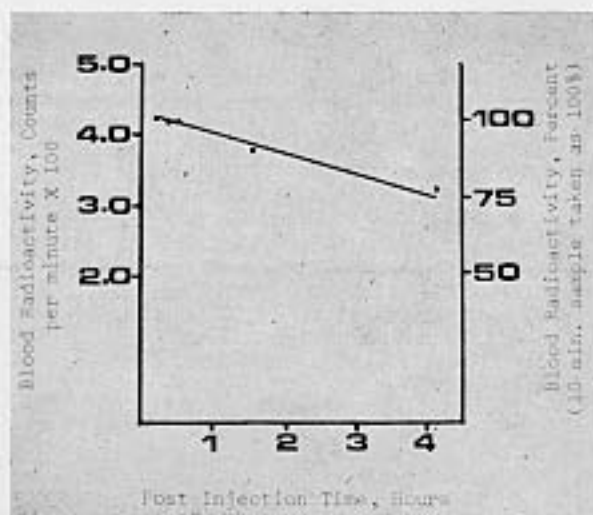


Fig. 1—Decrease of radioactivity in the blood of an elephant seal (M.a. 1) after it was injected with radioactive iodinated human blood serum albumin.

Blood volume determinations by the use of ¹³¹I-labeled albumin have consistently yielded greater values than exsanguination techniques. Two possible explanations exist for these differences. The first possibility is that the ¹³¹I-labeled albumin technique is measuring something more than blood volume in these marine mammals. Results of the present experiments with radioactive iodinated serum albumin disappearance rate and Evans blue dye blood volume determinations have demonstrated that this is not the case. The second, and most likely, possibility is that Scholander¹² was correct in his estimation that the exsanguination technique accounts for only about 75% of the total blood volume in seals. Therefore, the blood volumes of the seals of Bryden and Lim⁴ (16% of body weight by exsanguination) when corrected for blood remaining in the seal were very similar to those in the present study.

Seemingly, both the southern and northern elephant seals have mean blood volumes representing 20% or more of body weight. On the basis of available evidence, the elephant seal has the highest reported blood volume of any mammal.

References

1. Bert, P.: *Leçons sur la physiologie comparée de la respiration*. Baillière, Paris, 1870.
2. Best, C. H., and Taylor, N. B. (citing J. Welcker): *The Physiological Basis of Medical Practice*. 7th ed. Williams and Wilkins, Baltimore, Md. (1961): 17.
3. Bohr, C.: Bidrag til Svømmefuglernes Fysiologi. Kgl. Danske Videnskab. Selskab, 2, (1897): 207.
4. Bryden, M. M., and Lim, G. H. K.: Blood Parameters of the Southern Elephant Seal (*Mirounga leonina*, Linn) in Relation to Diving. *Comp. Biochem. Physiol.*, 28, (1969): 139.
5. Elsner, R., Franklin, D. L., and VanCitters, R. L.: Cardiac Output During Diving in an Unrestrained Sea Lion. *Nature*, 202, (1964): 809.
6. Field, T., Kaplan, E., and Terril, M.: Simplified Technique for Blood Volume Determinations Using I^{125}HSA . *J. Lab. & Clin. Med.*, 43, (1954): 332.
7. Harrison, E. J., and Tomlinson, J. D. W.: Observations on the Venous System in Certain Pinnipedia and Cetacea. *Proc. Zool. Soc. London*, 126, (1956): 205.
8. Harrison, R. J., and Tomlinson, J. D. W.: Anatomical and Physiological Adaptations in Diving Mammals. In *Viewpoints in Biology*. Vol. II. Butterworths, London (1963): 115.
9. Hlad, C. J., and Tanz, R.: An Analysis of Technical Errors in Radioalbumin Blood Volume Methods and Presentation of Modified Method. *J. Lab. & Clin. Med.*, 47, (1958): 289.
10. Marcilese, N. A., Valescchi, R. M., Figuerias, H. D., Camberos, H. R., and Varela, J. E.: Normal Blood Volumes in the Horse. *Am. J. Physiol.*, 207, (1964): 511.
11. Ridgway, S. H., and Johnston, D. G.: Blood Oxygen and Ecology of Porpoises of Three Genera. *Sciences*, 151, (1966): 456.
12. Scheffer, V. B.: Deep Diving of Elephant Seals. *The Murrelet*, 45, (1964): 9.
13. Scholander, P. F.: Respiratory Functions in Diving Mammals and Birds. *Hvalradef's Skifter*, 22, (1940): 60.
14. VanCitters, R. L., Smith, O. A., Watson, N. W., and Franklin, D. L.: Field Study of Diving Responses in the Northern Elephant Seal. *Hvalradef's Skifter*, 48, (1965): 15.
15. Wasserman, K., and MacKenzie, A.: Studies on the Seal During the Dive Reflex. *Bull. Tulane Univ. Med. Fac.*, 16, (1957): 105.